

## **CHAPTER 15: FAMILY OF CURVES AND THE ONE-POINT PROCTOR PROCEDURES**

### **Scope**

Highway embankments are composed of soil and/or aggregates placed in layers and compacted to an acceptable density. The purpose of a highway embankment is to provide adequate support of the overlying roadway and applied traffic loads. INDOT Specification Section 203.23 discusses the methods of density control for embankment construction using most types of soils and aggregates. Section 215.09 addresses the maximum dry density and optimum moisture of chemically modified soils. Embankment fill must be compacted to 95 percent of the maximum dry density with a moisture content within -2 and +1 percent of the optimum value. Subgrade compaction requires 100 percent of the maximum dry density.

At INDOT, the term “maximum dry density” refers to the soil or aggregate density as determined in accordance with AASHTO T99. AASHTO T99 sets forth a method of determining the density of a sample placed in layers in a certain size mold and compacted with a specified weight dropped from a specified height. The process is repeated on the same sample at various moisture contents. The resultant points are plotted on a chart of moisture content versus density. The maximum dry density and optimum moisture are found at the peak of the curve formed by joining the points.

Repeating the process for several different types of cohesive soils, yields graphs (i.e. curves) of similar shape and geometry. These similar graphs plotted on one sheet are called the Family of Curves, see AASHTO T-272. A copy of the INDOT developed Family of Curves is kept on file in each district in the Materials and Tests Department. The Family of Curves may be used to estimate the maximum dry density and optimum moisture content of a cohesive soil sample in the field. AASHTO T-99 is used to determine the values in a laboratory process.

Each layer of soil must be tested for density and moisture during embankment construction. In preparation for testing the soil, samples are taken from the jobsite cut areas or from proposed “borrow areas”. By carefully observing the soil layers or horizons in a cut, the INDOT technician may obtain samples of each soil type and submit those samples to the District Testing Department. The samples are processed in accordance with AASHTO T99 and the maximum dry density and optimum moisture content of each sample is reported to the project in the form of a lab report.

The process works well if the embankment is constructed from just one soil type in each lift of embankment. However, the normal process is not nearly as well defined. Each embankment layer being placed may contain different portions of two or more types of the soils as sampled. Now the problem becomes which target density and moisture content is most representative of that specific lift of embankment.

If the soil is cohesive in nature, the INDOT Family of Curves may be used. After the technician has conducted a field test to determine the actual field density of an embankment layer, a

representative sample of soil, approximately 7 pounds, is removed from the area around the test site. The maximum dry density and optimum moisture of soil sample is determined using the one point proctor method, AASHTO T272 Method A. The process involved is similar to that required in AASHTO T99. The moisture of the sample may be determined in accordance with ITM 506. The resulting wet density and actual field moisture content are plotted on the Family of Curves to determine which curve fits the point as plotted. The curve number is recorded and the data from the box in the upper right corner of the chart is used for maximum dry density and optimum moisture content.

The following example illustrates the use of the INDOT Family of Curves to select a maximum dry density and optimum moisture content for a density test. The process is the same for nuclear gauge tests.

### **Example Problem**

The technician gathers the following information:

1. A sand cone density test is completed in accordance with AASHTO T 191 to determine the wet density of an embankment lift (or layer). A moisture test will be required to calculate dry density, AASHTO T 217 (Speedy Moisture) or ITM 506 Field Determination of Moisture Content of Soils. The sample must be protected from drying until the initial wet weight of the sample is obtained. Use form IT 625.
2. A sample of the soil is obtained from the area immediately surrounding the sand cone test site. Sample size must exceed 7 pounds. A minimum of 1000 grams (2.2 pounds) is required for the moisture test in accordance with ITM 506 and approximately 4 to 5 pounds would be necessary to produce the molded soil sample for the one-point proctor. This sample need not be protected from drying.

The sand cone test results in the following: Wet Density of in-place soil was 123.0 pounds per cubic foot (pcf) and the moisture was 17.0 percent (%). The result was compared to the maximum dry density and optimum moisture content results from the one-point proctor test. The calculated dry density of the field sample is 105.1 pcf.

From the one-point proctor test, the following information was obtained.

A. Weight of prepared sample in the mold	9.60 pounds
B. Weight of the one-point mold	5.40 pounds
C. Net weight of Soil (A-C)	4.20 pounds
D. $C \times 30 =$ Weight of one cubic foot of soil	126.00 pounds
E. ITM 506 moisture revealed a moisture content of	16.6 percent.

By plotting 126.0 pcf on the vertical axis of the chart and 16.6% on the horizontal axis, Curve 6 is selected. See the attached Chart. The box on the upper right hand side of the chart lists the maximum dry density of Curve Six as 108.3 pcf at an optimum moisture content 16.8%. These values then become the target dry density and moisture content for the soil mixture being tested.

As previously mentioned, specifications require the moisture tested be within -2 and +1 of the optimum and the embankment layer to be compacted to at least 95 percent of the maximum dry density.

The site tested had a moisture content of 17%. This is within specification limits, -2 and +1 of optimum. The percent compaction is calculated by dividing field dry density by the target dry density and multiplying by 100 %.

$$(105.1 / 108.3) \times 100\% = 97.0\% \text{ of target.}$$

Specifications require 95 percent of target up to subgrade elevation. At subgrade the contractor is required to obtain 100 percent of target. The above test would pass for embankment construction below subgrade elevation.

The points plotted on the Family of Curves will not always plot directly onto one curve, that is, the plotted point falls between two curves. For example, if the one point proctor revealed a wet density of 131.0 pounds per cubic foot and the moisture content results was 14.0 percent.

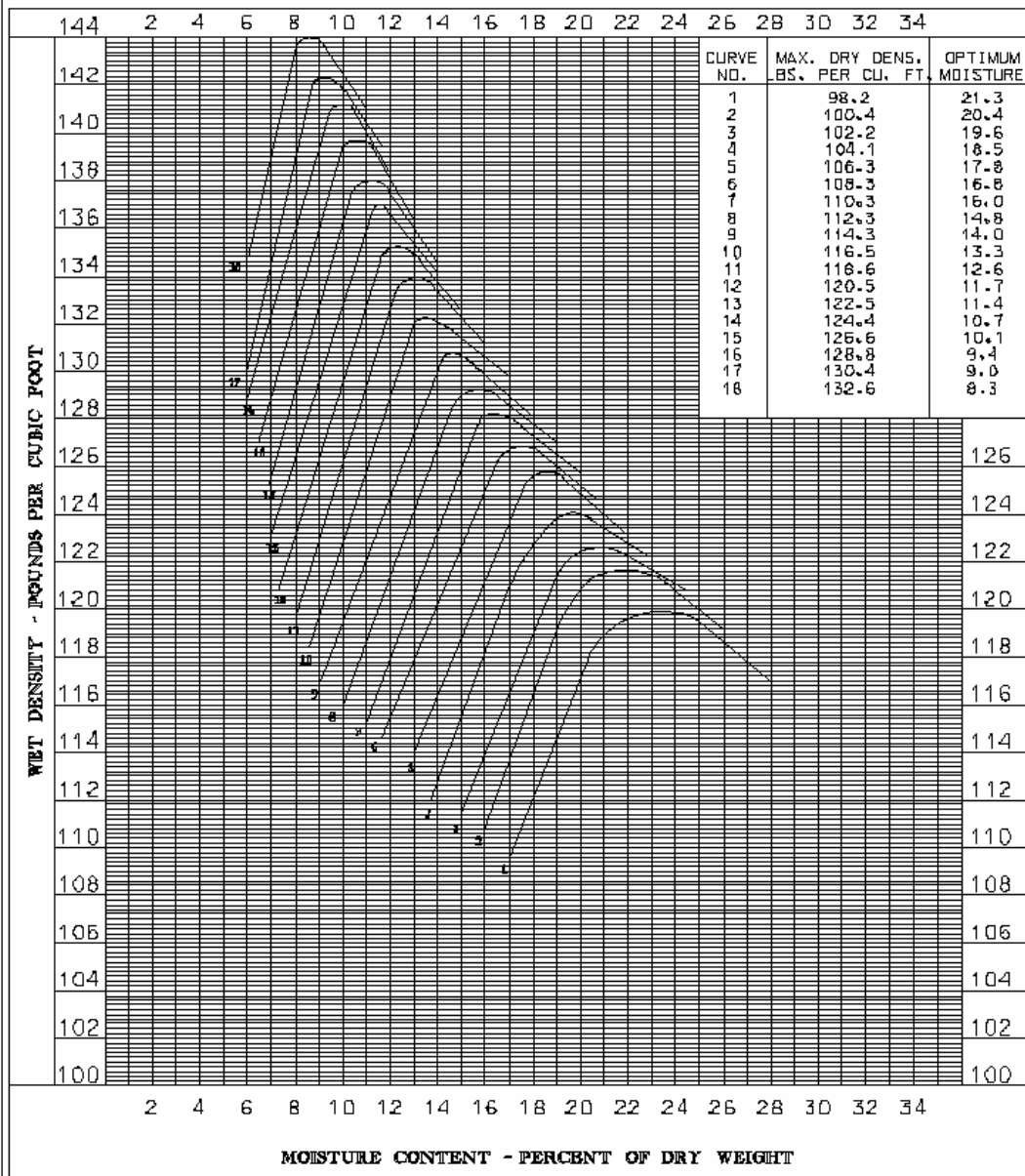
Plotting this pair of points on the chart would locate a point between Curve 9 and Curve 10. For this situation, the average of the curve data may be obtained to select maximum dry density and optimum moisture content. For these values the dry density target would be 115.4 pounds per cubic foot and the optimum moisture target would be 13.7 percent, the average of the data from the two curves.

It is recommended that the moisture used to plot on the Family of Curves be between optimum moisture and minus two percent of optimum. If the plotted points fall outside these limits, water may be added to the sample or the sample may be dried to allow the moisture to fall within the prescribed limits. The soil sample would then be recompact in the one-point mold and a new wet density calculated and moisture obtained.

# TYPICAL MOISTURE DENSITY CURVES

DIVISION OF MATERIALS & TESTS

INDIANA DEPARTMENT OF TRANSPORTATION



THESE CURVES NOT TO BE USED WITH GRANULAR MATERIALS (CURVES BASED ON DATA ACQUIRED FROM JULY 1965 TO JAN. 1969 BY SOILS DEPT.)